Enabling Monitoring and Inspection with Wireless Power and Data Hotspots Through Barriers

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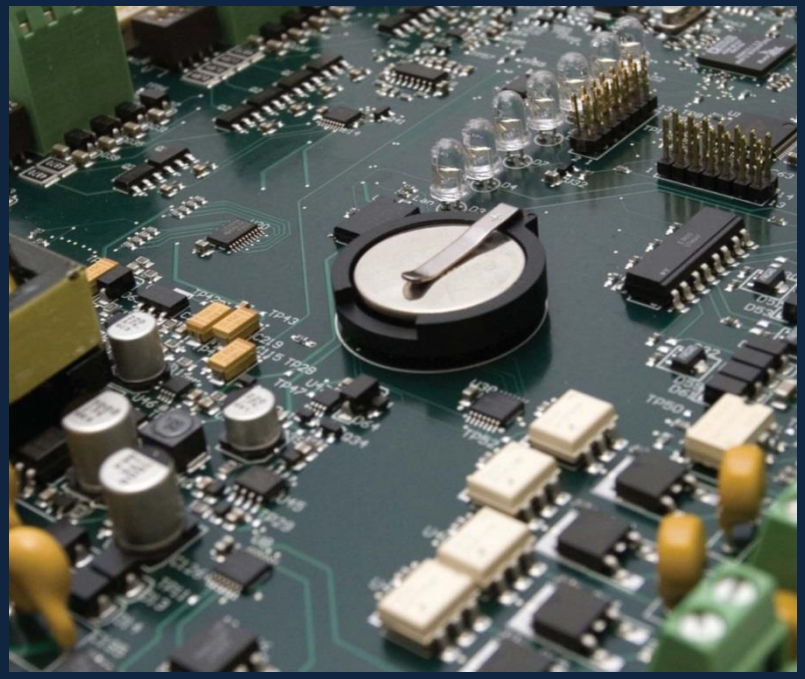
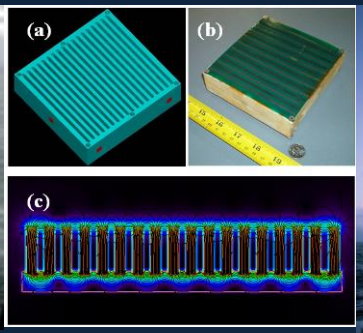
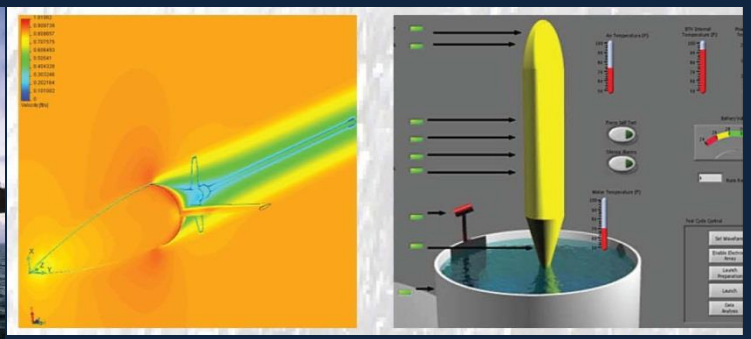






Small company at base of Rocky Mountains (Windsor, Colorado)

Research & Development

- Through barrier sensing, communications, and power

Application Specific Design

- Specializing in defense, oil and gas, and underwater technologies

Custom Electronics

- Pressure tolerant communications, control, and data acquisition platforms

What is the problem?

- Harsh environment are typically contained or isolated using conductive materials (Steel, Aluminum, etc.)
  - Oil and gas pipe contains high pressure high temperature
  - ISS contains 1ATM from vacuum and large temperature fluctuations
  - Submarine contains 1ATM from subsea pressures

- Want to make measurements and pass data through these barriers without making a penetration

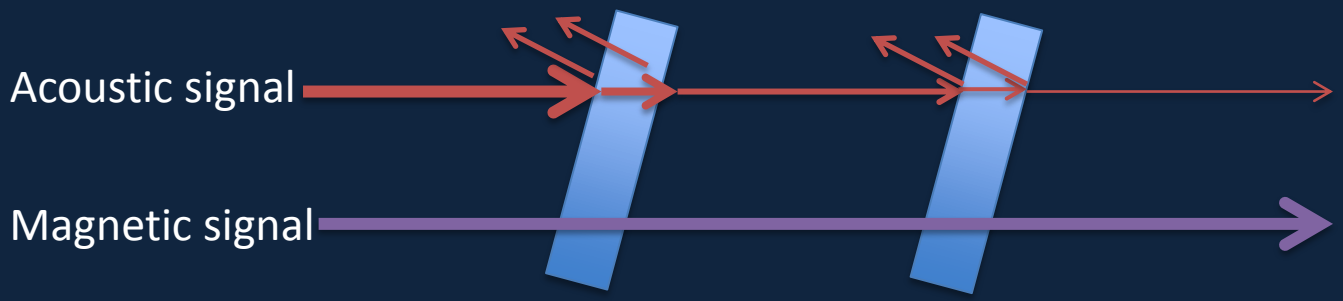
Why Magnetic Based Wireless and Sensing Instead of RF?

- RF is limited by conductivity of a media. As such communications or sensing through most metals is impractical
- Magnetic field penetration is (at low frequencies) dominated by magnetic permeability.
- Comparing attenuation through air versus common structural materials, magnetic fields are much less affected
- Additionally, magnetic fields can wirelessly transfer significant amounts of power

	Air	Carbon Steel (1010)	Ratio
Conductivity	3.0×10^{-15} S/m	7.0×10^{6} S/m	2×10^{21}
Relative Magnetic Permeability	1.0	1.0×10^{3}	1.0×10^{3}

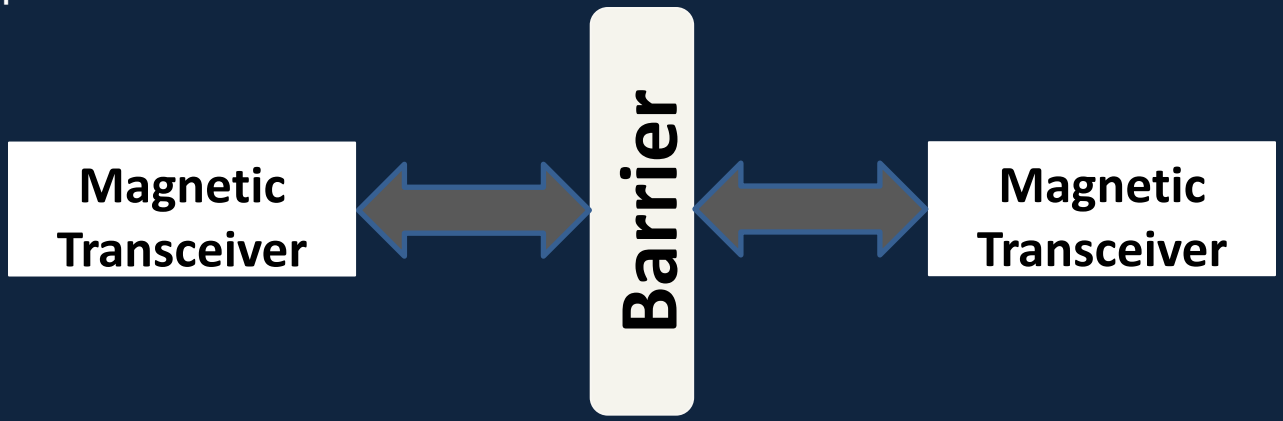
Why Magnetic Based Wireless and Sensing Instead of Acoustic?

- Acoustic communications is strongly limited by the path and variations in acoustic properties of the path. Through thin (<1m) materials, multi-path reflection causes major distortion.
- Multipath reflection in acoustics is an issue due to the relatively slow propagation speed of acoustics. With magnetic fields the propagation is on the order of the speed of light and thus multi-path distortion is avoided at reasonable scales.

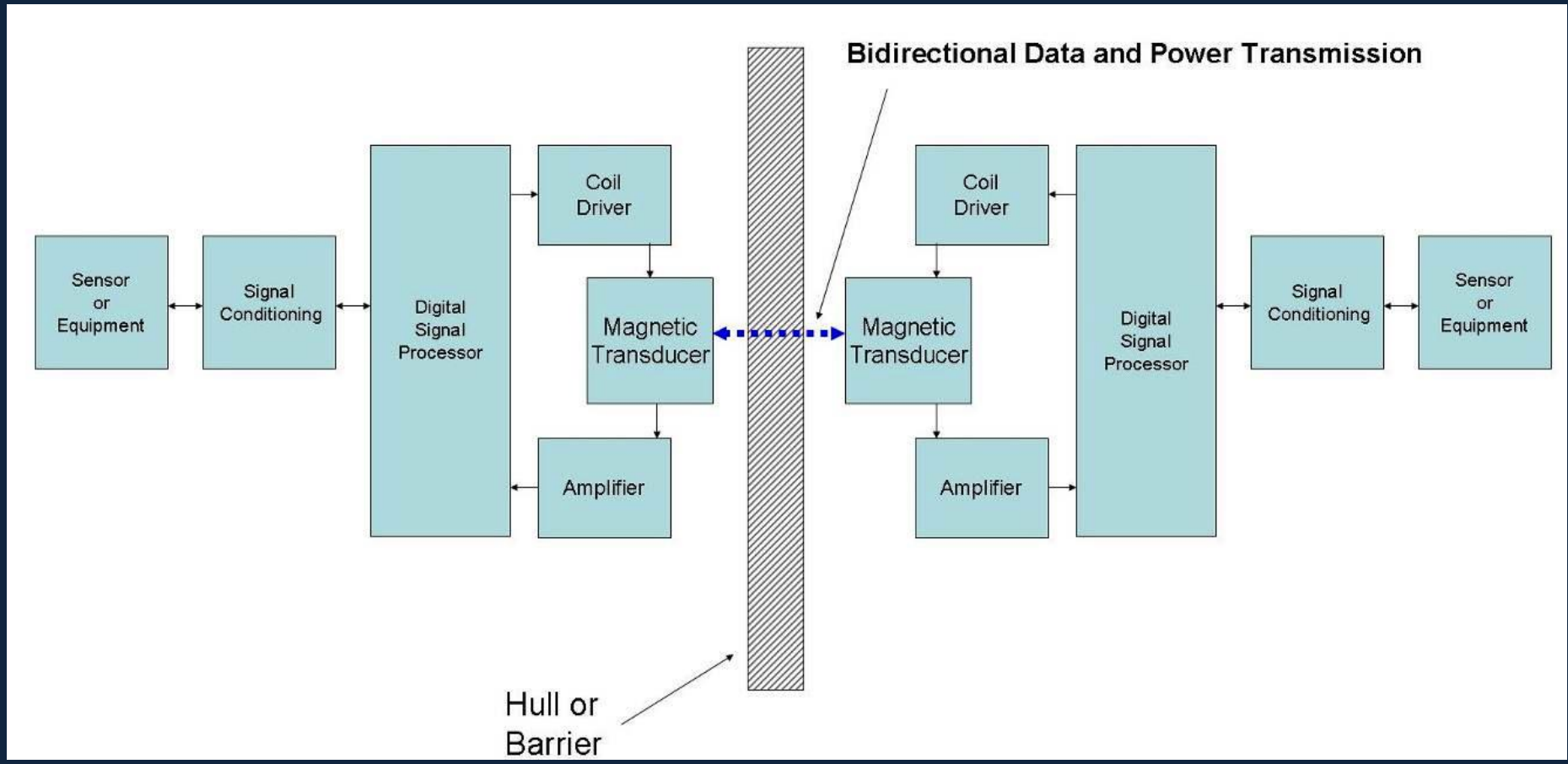


WiΨ - Wireless Power and Signal Interface

- System uses the modulation of magnetic fields to transmit data and power wirelessly
- Works through metals (incl. X65, 1010, Inconel, Super Duplex, aluminum), seawater, concrete, air, and layers of multiple materials
- Deployed on a US Navy Los Angeles class submarine as part of a mission and safety critical system
- Recent work focused on application specific oil and gas embodiments as well as major overall technology improvements

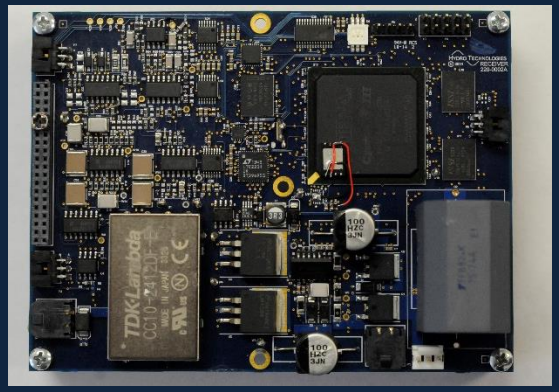


WiΨ – Block Diagram



WiΨ Hardware

3.5”

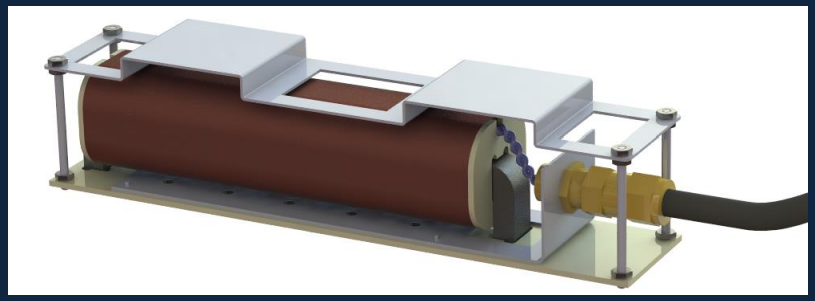


WiΨ RX: sends power through barrier. Demodulates received data signal. FPGA software defined radio architecture for configurability in new applications. RS485 interface to other data acquisition/logging equipment.

WiΨ TX: inductively powered through barrier. Interfaces to analog or digital (RS485) data sources. Sends modulated data through barrier

0.8”

4”-12” depending on application



WiΨ transducer: used for both RX and TX. On TX side, it generates a magnetic field. On RX side the transducer converts a magnetic field to a detectable voltage. Both power and data can be sent over the same transducer link

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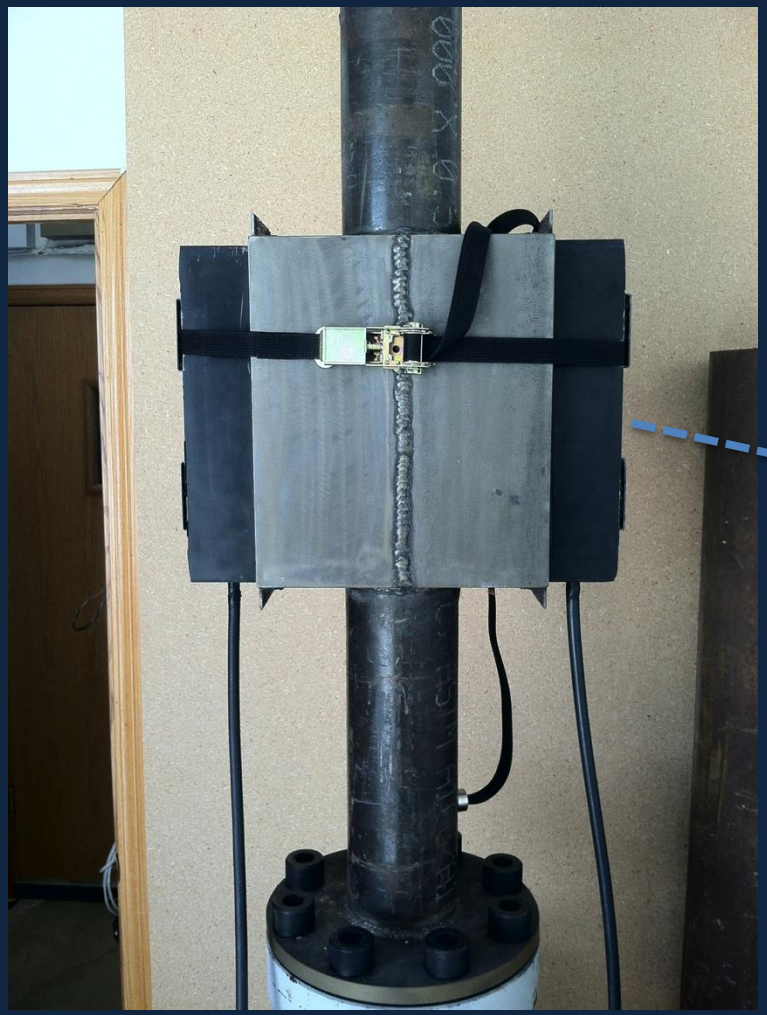
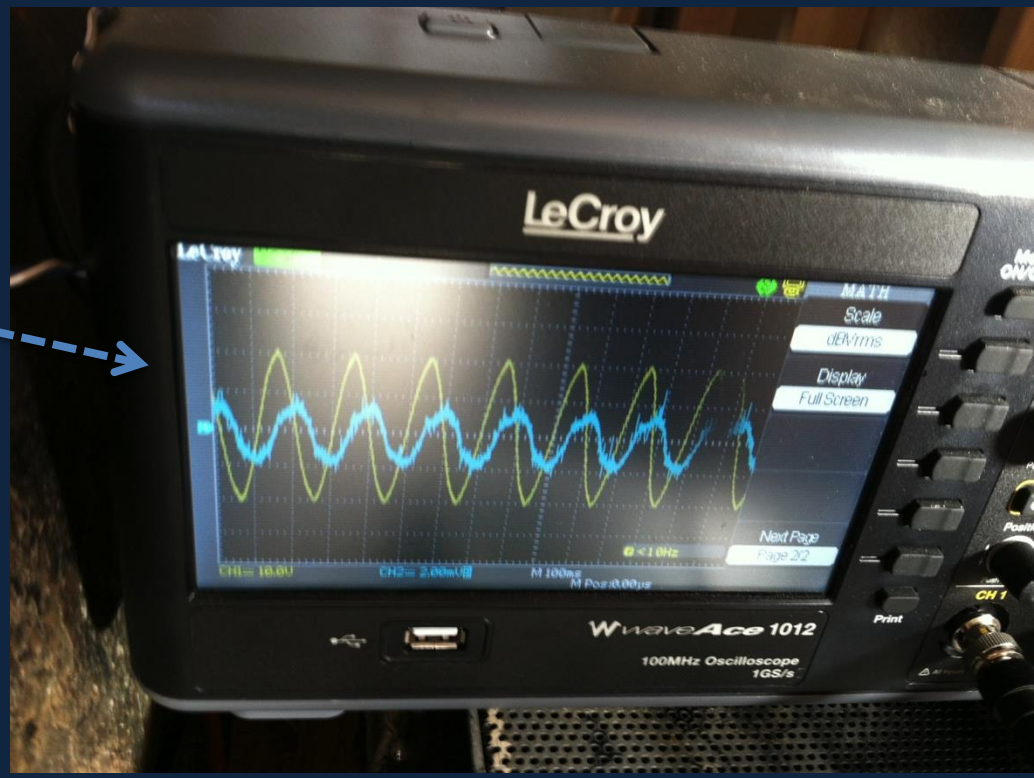
Extreme Example of Magnetic Communications

- sensor data through 12” of structural steel





FSK modulated receive data
(yellow is TX signal, blue is RX)

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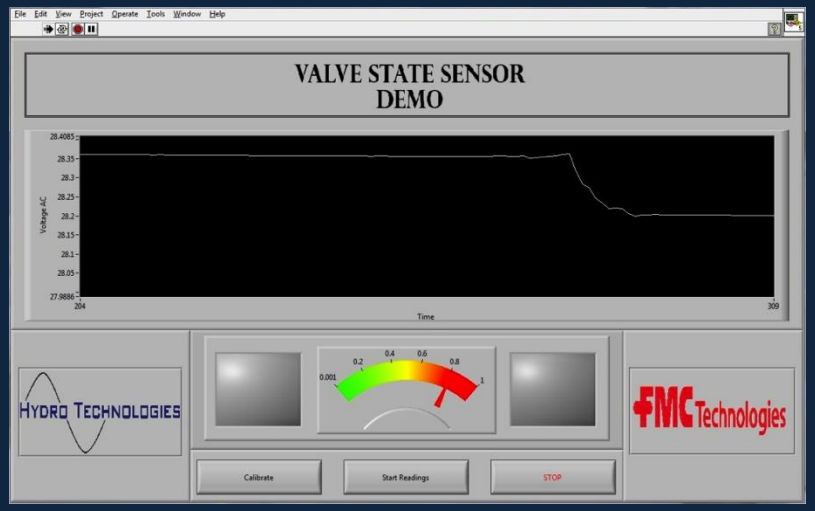
Non-penetrating Valve Sensor

- In this application phase and amplitude of received data signal indicate path obstructions
- Allows us to sense the presence of a valve gate from the outside

Sensor installation



Demo software

Sensor registers 100% opened.

Sensor registers 50% opened.

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WiΨ Data Rate and Power Transfer Through Various Materials

Material	Thickness	Data Rate	Power Transfer
304 Stainless Steel	0.5”	500 kbps	5W
	1”	100 kbps	1W
Titanium	0.5”	500 kbps	5W+
Inconel	0.5”	500 kbps	100W
Aluminum	0.5”	100kbps	1W
Plastics or other low conductivity media	0.5”	1 Mbps+	5kW+
Steel (1010, X65, 4130, etc)	1”	1 kbps	~1mW *
Steel (1010, X65, 4130, etc)	7”	10 bps	-

*** Recent advances may lead to radical improvement in high μ material power transfer**

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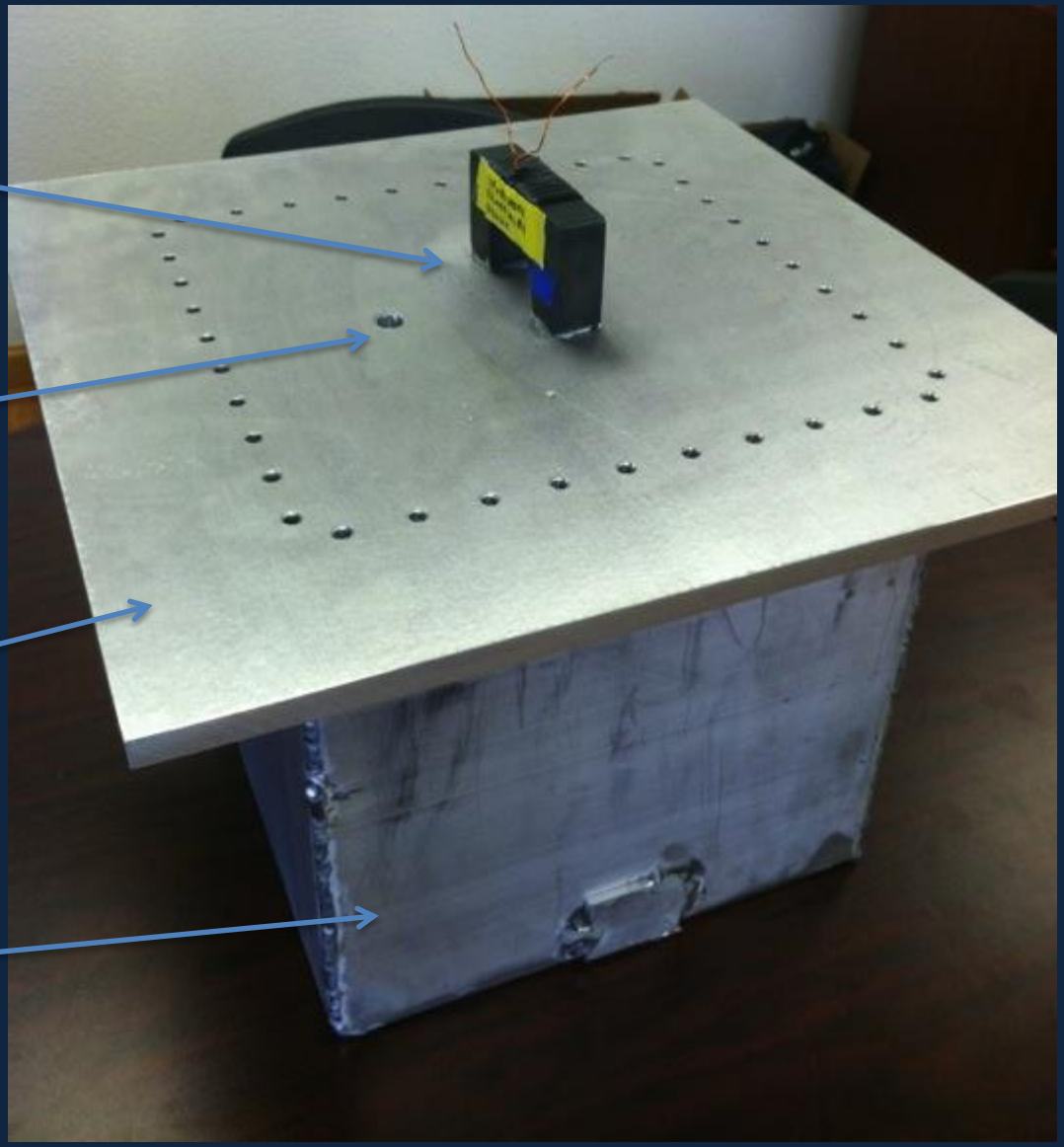
WiΨ System Can Also Detect Barrier Breach

Receiver (magnetic "transmitter" enclosed in box)

Hole, varied in test from 0.06" to 0.5"

Lid (1/2" aluminum), not bolted down in this image

Sealed (welded) ¼" thick 12"x12" aluminum box



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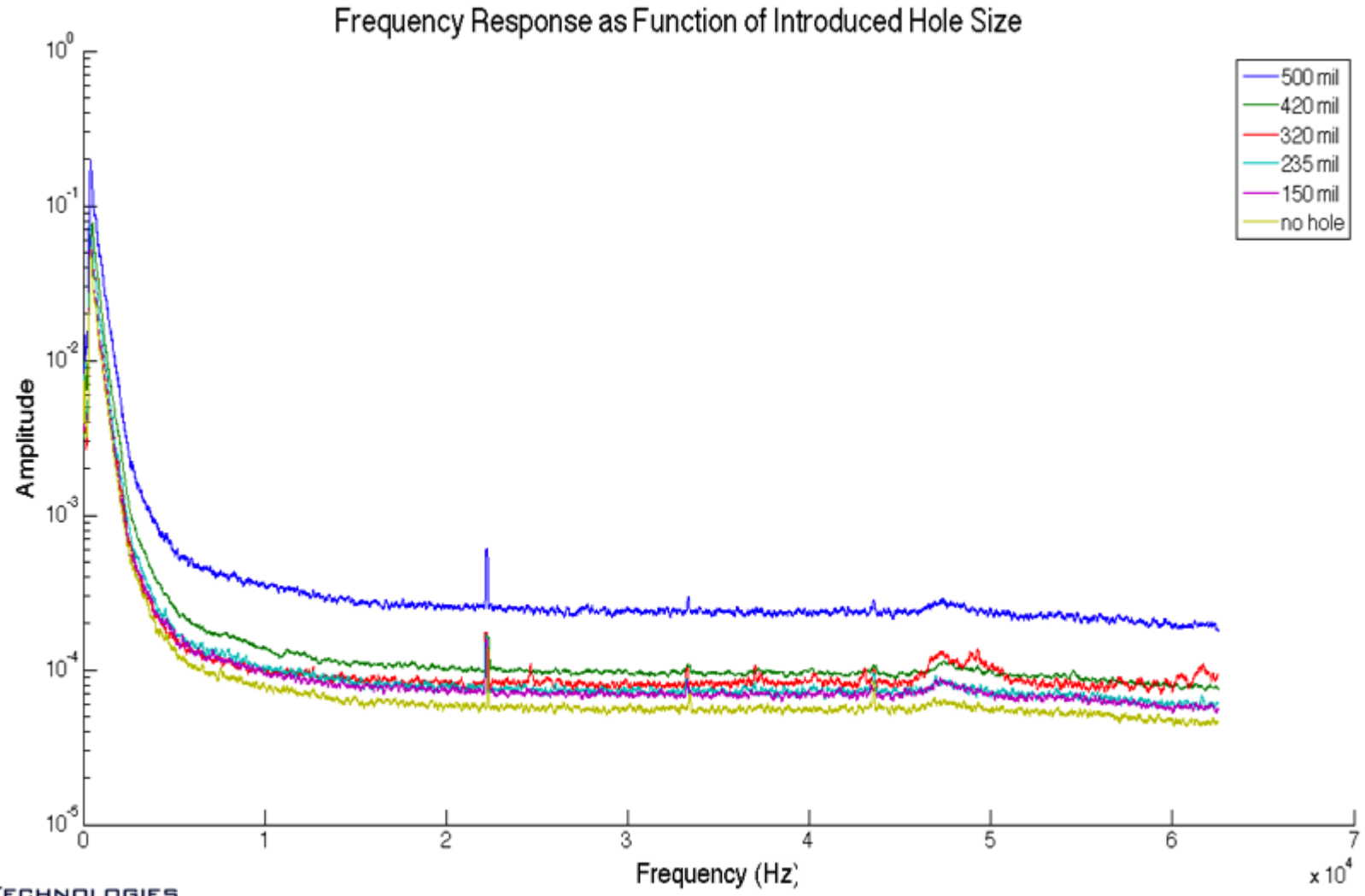
Swept frequency probe can be done along with power and data transmission



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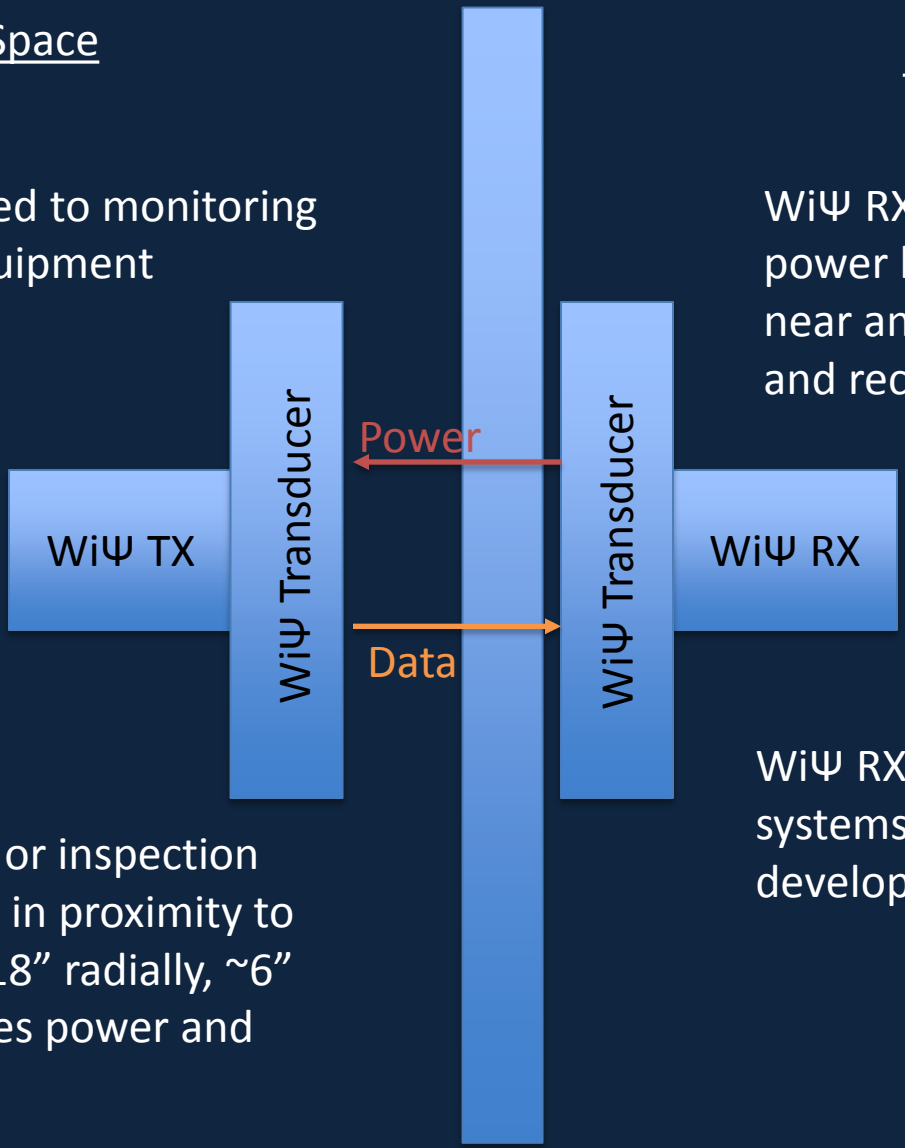
Wireless Power and Data HotSpot Concept

Space

Inside ISS or vehicle

WiΨ TX connected to monitoring or inspection equipment

WiΨ RX powered by station power bus. Senses when TX is near and begins sending power and receiving data.



When monitoring or inspection equipment comes in proximity to hotspot (within ~18" radially, ~6" standoff) it receives power and can send data

WiΨ RX connects to any inboard systems. RS485 currently but can develop other interfaces.

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Potential Monitoring and Inspection Applications with WiΨ HotSpot

- Interface with traditional eddy integrity sensors.
- Charge batteries or super-capacitors on inspection or monitoring equipment
- Charge and download data from extra-vehicular inspection robot moving along hull
- Provide primary or backup hull integrity monitoring
- Provide a through-barrier hotspot for multiple inspection and monitoring sensor platforms
- Allow wireless pressure, temperature, and level sensing through barrier in fuel tank. Feasibility being evaluated for use in liquid oxygen and liquid hydrogen tanks under in collaboration with NASA Marshall Space Flight Center.

The Take Home

- WiΨ can be used for:

1. Data communications through thick, conductive barriers or layers of conductive barriers
2. Transferring power through conductive barriers
3. Characterizing changes in a barrier (i.e. holes, moving valve gate)

Or a combination of the above